Solved! Making the case for collaborative problem-solving

Other

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Wayne Holmes
with Michael Mann

March 2017

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About this report

This report was commissioned by Nesta and researched and written by **Rose Luckin**, **Ed Baines**, **Mutlu Cukurova** and **Wayne Holmes** from the UCL Knowledge Lab and the UCL Institute of Education. It was edited by **Michael Mann** with support from **Matt Stokes**.

The report primarily focuses on upper primary and secondary-age education, but also brings in perspectives and research from higher and further education contexts. Lower primary contexts are not addressed in our secondary research due to a lack of research, but examples of good practice come from across age ranges.

Authors

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About Nesta

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Foreword from Nesta

Every generation has to ask anew what skills and knowledge are most essential for children to learn. Some of the answers change little – like being able to read and write, or to master maths. Others go in cycles.

The evidence set out in this report confirms a great deal of research which has shown the rising importance of a cluster of skills that are both very ancient, and very relevant to the near future.

These are skills in solving complex problems, and working with other people as well as machines to solve them. Such skills, look set to be increasingly relevant not just to many of the jobs that will survive new waves of automation, but also to our ability to cope in everyday life.

This should be obvious. Yet public policy, and everyday practice in schools, has in some respects moved in an opposite direction.

That's why at Nesta we commissioned research from UCL to find out what was known about teaching and learning collaborative problem-solving.

Collaborative problem-solving sits at the intersection of non-routine problem-solving and social intelligence. At its simplest level, it is about solving problems together, applying knowledge and discussing with others what will work best.

A simple example is times tables. These are useful tools for helping children become familiar with numbers. But they're predictable and routine. A 'non-routine' problem requires us to use a range of skills to come up with a solution that is new and unknown to the solver. It forces us to discover, to understand and to make sense. Instead of asking *"What's 10 x 2?"* you might ask a group of children to work out how much paint is needed to paint a classroom. A somewhat more complex example would ask students to work out how the school could cut its energy bill by 10 per cent, drawing on knowledge about how heat and light are produced, the characteristics of the school building, as well as basic maths and economics.

This report from UCL finds that if structured well, these problems can reinforce knowledge and improve attainment, as well as prepare children for the future workplace. But it also tells us that the barriers for teachers are substantial, from curriculum coverage and behaviour management, to designing a task that both stretches and supports. For collaborative problem-solving to gain ground a concerted shift is needed, including teacher training, better resources and system-level support.

Many of the most powerful decision-makers in education have been sceptical about this, and see it as a distraction from the more traditional transmission of knowledge. On the opposite end of the spectrum some have advocated that discovery and problem-solving can substitute for acquiring knowledge. Both positions are untenable, and increasingly unhelpful in a world where, for both life and work, we need both knowledge and skills.

This year attitudes are likely to start changing. In 2017 the OECD will publish its first country rankings for collaborative problem solving. PISA ratings for maths, reading and science have become a prominent feature of educational debate and media coverage. The OECD has recognised for some time that these subtler skills are becoming more important, and has been keen to ensure that the metrics keep up with the reality. National policymakers are likely to follow.

Building on this report we see five priorities for action here in the UK.

The first is to ensure that there are much better resources for teachers to use, from primary level upwards, and better training for teachers. We suggest working with subject associations (e.g. NCETM for maths, or The Geographical Association) and publishers to develop a bank of curriculum-aligned, collaborative problem-solving (CPS) lesson ideas, as starting points for teachers to adapt. We also suggest working with teacher training providers to develop key-stage-specific CPS training modules, to give teachers knowledge, expertise and confidence, as well as subject-specific CPS innovation prizes and teacher resource sharing platforms.

Secondly, funding is also needed for the best existing programmes to help them grow and assess their impact. That could mean grant funding for pilots or evaluation of promising projects (e.g. Nrich's 'Being Collaborative' resources) or support to scale programmes in this space which already have good evidence (e.g. Philosophy For Children).

A third is to draw on more resources from beyond schools, involving volunteers and following the lead of peer and volunteer-powered programmes like Franklin Scholars or The Access Project, and bringing together large employers which value these skills to support them more directly through CSR and volunteering activities.

Fourth, more work on assessment is needed. The 2014 national curriculum made a step in the right direction, introducing a problem-solving focus in some subjects, but much more can be done. Building on the OECD's collaborative problem-solving rankings this year, government should begin small-scale, annual assessment trials, to systematically learn what can be measured for both low and high-stakes assessment.

A fifth is to work with universities so that the new Teaching Excellence Framework (TEF) and National Student Survey (NSS) can gather evidence about the effectiveness of methods to promote collaborative problem-solving, as well as working with collaborative MOOCs like Futurelearn or altMBA.

Every young person needs to learn how to solve problems with others. Few skills will matter as much for their personal lives, their working lives, or for their ability to contribute to the much bigger challenges of the century they're living in. Many in education are deeply committed to cultivating just such skills. But they in turn need help, to generate tools, evidence and a supportive environment. We hope that in a small way this report, and the programme it is part of can help that happen.

Geoff Mulgan
CEO, Nesta

Introduction from UCL

The importance of the knowledge construction process has never been more crucial for learners of all ages. The ability to understand something sufficiently to satisfy standardised assessments is no longer enough. Learners must now also be able to explain, synthesize with the knowledge of others, justify and revise their understanding, and apply their knowledge to solve problems. This process of collaborative problem-solving, that is, solving problems with others, can support learning and exemplifies the essential skills for the modern workplace.

However, few students are exposed to high quality collaborative problem-solving, and few receive training in the cognitive and social skills required for it. The need for concerted action to mobilise and scale collaborative problem-solving in education is made more urgent by the inevitable onslaught of workforce automation. The routine cognitive skills that are the focus of most education systems are the easiest to automate, but it will be higher order problem-solving and social skills that will be at a premium.

In this report we clarify what is meant by collaborative problem-solving and probe the evidence about its learning effectiveness. Collaborative problem-solving brings together individual problem-solving and the social process of more than one learner working together on problems no individual can solve alone. We identify examples of innovation in collaborative problem-solving practice, along with barriers and enablers.

The clear evidence from research involving well designed and managed collaborative problem-solving, **highlights its huge potential alongside traditional approaches to instruction**, including opportunities to improve student attainment. This is true across all education sectors.

The promise shown by several decades of research about collaborative problem-solving is not reflected in educational practices, other than in small pockets. The situation is complicated by the range of terminology that is used to describe what could be collaborative problem-solving, but is often either collaborative or problem-solving, not both. For example, Enquiry-Based Learning (EBL), Problem-Based Learning (PBL) and Project-Based Learning (PjBL) can be done in groups and often involves problem-solving, but can also be done by individual learners. Appearances can also be deceptive. Even when students are sat in groups, giving the appearance of working together, there may in fact be few opportunities to actively collaborate in ways that are cognitively enhancing.

The problem of terminology is exacerbated when identification of a teaching approach fails to recognise its inherent complexity. For example, the 2015 PISA report (results released in 2016 and later in 2017) appears to show that frequent exposure to enquiry-based instruction is associated with lower scores in science. The identification of 'exposure to enquiry-based instruction', as opposed to 'teacher-directed instruction' was achieved by asking students questions, such as whether or not they were encouraged to experiment and engage in hands-on activities. The problem caused by this method of identification is exemplified in the paradoxical results attributed to some individual countries. Korea, for example has the lowest amount of teacher-directed pedagogy and yet they also have the second lowest amount of enquiry-based pedagogy too. This doesn't make sense and confirms the importance of taking great care both when defining a teaching approach and when identifying a teaching approach in action.

Collaborative problem-solving does not happen spontaneously. Both teachers and students require experience, training and practice to employ collaborative problem-solving effectively, and yet there is little evidence of a concerted effort to do this. This means that when teachers do attempt to employ collaborative problem-solving, the quality of the group interactions and dialogue can be poor.

The future for collaborative problem-solving is not currently as bright as it should be and there is clearly a role for Nesta to play in helping organisations to embrace and reap the potential of collaborative problem-solving. There are, however, significant barriers to adoption; these include the prevalence of individually driven and assessed education systems, the wariness with which many educators and students view collaborative problem-solving and the lack of educator and student skills and training. There is a slightly more positive outlook for higher education, and the introduction of the Teaching Excellence Framework (TEF) could enable more systematic monitoring of teaching practices and encourage further take up of approaches like collaborative problem-solving.

Section One: Definitions

- Collaborative problem-solving is a way of solving problems with others, where participants share a goal and a level of equality. We position it as a subset of collaborative learning, with connections to research on problem-solving and enquiry-based learning.

- Collaborative problem-solving is an area of growing interest for those looking at the changing nature of both the workplace and national labour markets, as demonstrated by the OECD's inclusion of it in their 2015 international education PISA survey (results released in 2016 and later in 2017).

- Educators can support collaborative problem-solving, but it is also dependent on participant knowledge, skills and attitudes, and therefore cannot be guaranteed.

- Collaborative problem-solving requires the use of knowledge. It involves applying, explaining, and synthesising knowledge in different ways or with different people.

Collaborative problem-solving brings together thinking about the separate topics of collaboration and problem-solving, each with its own research history.

The combined term is an area of interest for some looking at changing workplace needs. For example, the OECD included collaborative problem-solving as one of the four topics assessed (alongside mathematics, English and science) in their 2015 PISA survey (some results pending).

There are different definitions for collaborative problem-solving, ranging in detail. In layman's terms, we might simply describe it as **solving problems together**. From an academic perspective, a common definition now is *"the process of a number of persons working together as equals to solve a problem"*. The OECD go further for their PISA assessments, specifying it as:

> *The capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills and efforts to reach that solution.*

OECD, 2015

The relevant literature goes back 50 to 60 years and uses a range of different but overlapping terms, including cooperative learning, collaborative learning, peer co-learning, peer tutoring, peer assisted learning and more. Some authors use these terms specifically, others interchangeably. Either way, this makes it difficult to classify studies with respect to the different approaches.

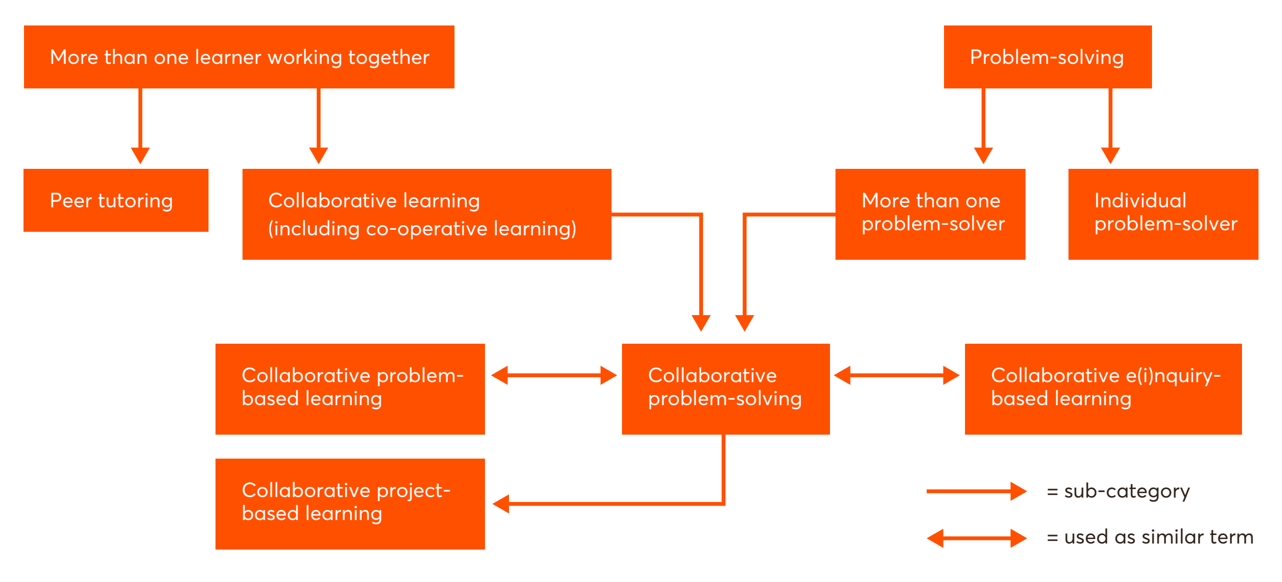
What is clear, however, is that collaborative problem-solving is more than individual problem-solving in the company of others. It requires a set of sophisticated interaction skills, used at the same time, to support the thinking of others, to coordinate their thinking with one's own, and to achieve a mutually agreed goal.

To understand the term and relevant research, it is important to understand its component parts and associated concepts. Figure 1 illustrates the relationships between the main terms.

We define collaborative problem-solving as a subcategory of collaborative learning.

In the rest of this section, we discuss the constituent parts of collaborative problem-solving and ground it within the relevant wider literature.

Figure 1: The terminology of collaborative problem-solving



What is collaboration?

At a basic level, the verb to collaborate means to work together. In this sense, it pre-supposes conditions of cooperation (agreeing to work together, multiple parties contributing) and social coordination (awareness of others' contributions, coordination of behaviour).

Collaboration is also more than these two. It can involve participants working in unison, oriented to a jointly agreed goal and often generating ideas to form the basis for a solution or decision. There is also a sense in which collaborative learning involves working together in unison to complete a task, whilst cooperative learning can involve individuals undertaking different sub-tasks but cooperating in the overall endeavour.

Many assume that collaboration is a natural interaction, which takes place when people are brought together to work on a task. In practice 'collaboration' is not inevitable. With the wrong attitude, skills, or set-up, a group task can easily result in interaction that is one-sided or where a person dominates and imposes their view. Collaboration is therefore dependent on the skills, attitudes and positioning of the participants relative to each other and the specific task confronting them. An educator can only create the circumstances that will make collaboration more likely to take place and the circumstances that will sustain it.

The overlaps between terms create difficulties in analysing the literature, as collaborative learning and cooperative learning are used interchangeably in the vast majority of meta-analyses and research reviews. We found two definitions helpful in distinguishing these two concepts, when faced with situations when individual learners are working together. However, it is still difficult to distinguish between collaboration and co-operation within the literature, because there is often insufficient detail about how, and in what circumstances individuals were working together.

Littleton and Mercer (2010) provide an eloquent account of collaborative learning that highlights some key features. These include that participants are:

- Engaged in a coordinated, continuing attempt to solve a problem or construct common knowledge.
- Involved in a coordinated joint commitment to a:
  - Shared goal
  - Reciprocity
  - Mutuality
  - The continual (re-)negotiation of meaning
- Likely to experience groupsense or a feeling of shared endeavour.
- Must establish and maintain intersubjectivity or recognising that they have a shared understanding about their endeavour.
- Must maintain a shared conception of the task or problem.
- Must engage in interthinking: thinking together.

In order to help differentiate between collaboration and cooperation Damon and Phelps (1989) introduce two terms:

- **Equality**: a situation where participants are equal in status and participate in a two-way dialogue taking direction from one another.
- **Mutuality** a situation where discourse is extensive, intimate and connected, in other words all individuals are engaged and 'on the same page' when it comes to the intentions of their working together.

What is problem-solving?

Putting collaboration aside, and focusing on problem-solving, the draft framework for the Problem-Solving domain in PISA 2012 (OECD, 2010) defines problem-solving as:

Problem-solving competency is an individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen.

A recent publication by Leadbeater sees problem-solving as a richer concept in which problem-solvers: *"deploy knowledge in action, to work with others and to develop critical personal strengths such as persistence and resilience, to learn from feedback and overcome setbacks."* This assumes collaboration as part of the problem-solving process, but helpfully also specifies the process as involving knowledge in action and overcoming setbacks.

This resonates well with Marzano (1988), who has been highly influential on the OECD's definition and more widely in education. Marzano identified four knowledge utilisation processes:

- Decision-making.
- Problem-solving.
- Experimental inquiry.
- Investigation.

Marzano described the process of problem-solving as happening when a learner attempts to accomplish a goal for which an obstacle exists (influenced by Rowe, 1985). Problem-solving requires the learner to use their existing relevant knowledge about the problem, retrieve prior knowledge, both about the subject matter of the problem and about the process of problem-solving, from memory that is relevant to the problem situation. The learner must identify the obstacle to problem solution, evaluate alternative goals and associated actions by processing information, select from these alternatives and put the selected goal oriented action into force.

What is collaborative problem-solving?

Collaborative problem-solving brings together individual problem-solving and the social collaborative process of learners working together. In the social domain, it is important to establish a joint understanding of the problem and then to negotiate the route to the solution, through processes of interthinking and argumentation. The OECD identify three dimensions for collaborative problem-solving: context, task and process. These three dimensions help us to unpack the concept of collaborative problem-solving.

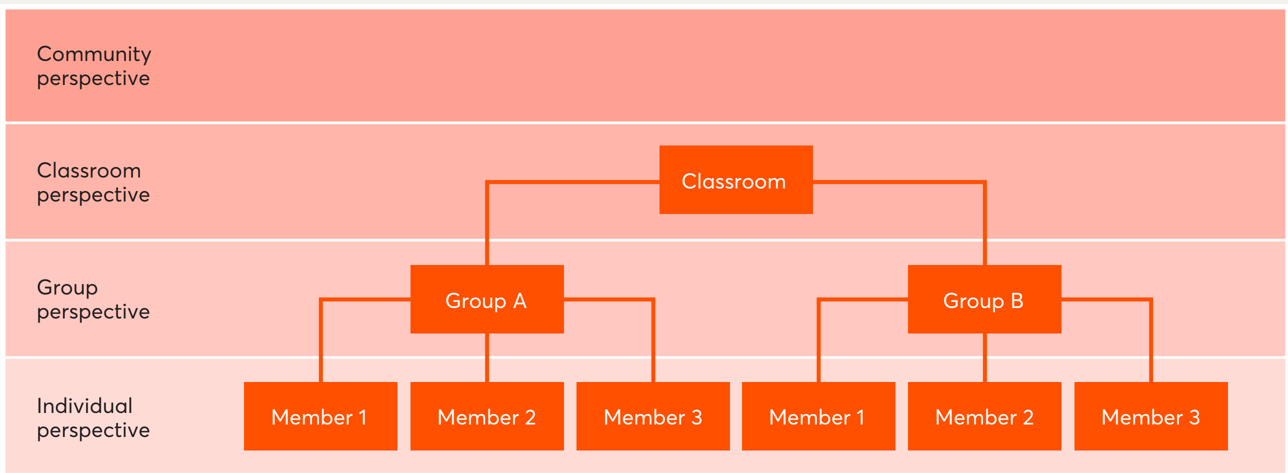
Context can also be described as the circumstances of the problem being solved. It consists of the resources that are available to learners to support their collaborative learning activity (Luckin, 2010). It relates to a wide range of elements including the content focus of the task, its relation to other aspects of the curriculum, the resources and tools associated with doing the task.

Task: A collaborative problem-solving task can be thought of as a gap or crossroads where the way forward is to an extent unknown and must be generated and/or co-constructed by two or more participants. The task might be as much about identifying a way forward as about acting a solution or finding 'the answer'. The task should encourage members to be mutually interdependent. This can be achieved through the task design or other means, such as rewards and/or group roles.

Process: The process of collaborative problem-solving requires the combination of social and cognitive processes. Ideally joint problem-solving will centre on a number of parallel cognitive activities, such as understanding the problem situation, clarifying sub goals and reflecting on assumptions.

The OECD's 2015 definition is not yet complete in its reflection of collaborative problem-solving. The OECD approach was developed for assessment purposes and results in a couple of limitations. First, the process of collaborative problem-solving is only considered from an individual capacity perspective. This makes sense from the OECD's perspective since PISA assessments are done at individual level. However, collaborative problem-solving is a multilevel process and needs to be considered from different perspectives which must reflect the needs of individuals, groups and communities (see Figure 2). Recent research evidence (Dillenbourg and Jermann, 2007) suggests these different perspectives should be taken into account in the design and investigation of collaborative problem-solving processes. Second, the OECD's approach does not include some important components of problem-solving such as a tuition approach. For example, it does not take into account the important element of participants' knowledge deficiency (Cukurova, Avramides, Spikol, Luckin, and Mavrikis, 2016), even though this dimension is considered as essential for problem-solving processes (Hmelo-Silver, 2004).

Figure 2: The different perspectives on collaborative problem-solving



Related concepts and terms

A note on knowledge

Before we continue with the findings of our report we want to make clear that we are not suggesting that collaborative problem-solving should be the only method of teaching and learning used within education, nor do we disregard the importance of knowledge. We argue for a broad range of teaching and learning approaches that are selected and blended effectively according to the needs of learners, teachers and their contexts.

Knowledge and a thorough understanding of the subjects being studied continues to be important. However, students must also be able to apply this knowledge, to explain it clearly to others, to synthesise it with knowledge from other subject areas, and be able to use it to solve problems collaboratively. Subject specific knowledge and routine cognitive skills are the easiest for us to automate with technology and these alone are no longer enough in the modern workplace. As science and technology continue to progress the notion of a body of knowledge will increasingly be something that will be distributed amongst multiple intelligences, both human and machine. It is therefore even more important for students to understand what they know and what they don't know, to have excellent metacognitive awareness as well as subject knowledge.

Problem-based learning and e(i)nquiry-based learning

Within post-16 education, there is a range of terms that broadly refer to problem-solving by more than one person working collaboratively. Two well known bodies of research and practice are Problem-Based Learning (PBL); and Enquiry-Based Learning (EBL, or Inquiry-Based Learning in the United States - IBL).

There have been attempts to distinguish these from each other, but there remains significant overlap and inconsistencies in their use. Different names to some extent reflect origins, whether geographically or in terms of an academic discipline. Problem-Based Learning has its origins in medical education in Canada, and also has strong associations with disciplines like chemistry and engineering. Aalborg University in Denmark, for example, hosts a UNESCO Chair of PBL in Engineering Education. The origins of Enquiry-Based Learning can be traced back to North America, but also has strong roots in the UK, where a Centre for Excellence in Enquiry-Based Learning (CEEBL) was established at Manchester University in 2005. A recent Nesta publication on Challenge-driven Universities[1] identifies a number of international and UK universities that are using an EBL approach, including Stanford School of Engineering, the Norwegian University of Science and Technology, and the Royal College of Art.

Section Two: Findings from the literature

- There is strong evidence that collaborative learning can raise levels of pupil achievement as measured by standard grading and assessment criteria, as well as evidence of positive effects on pupil attitudes, motivation and classroom climate.

- There is good evidence that problem-solving approaches can impact educational outcomes, but it depends on how they are used. Some studies also suggest that problem-solving has more impact when collaborative, rather than competitive.

- The promise of CPS approaches contrasts with practice. Evidence from the UK and abroad suggests that structured collaborative problem-solving activities in schools are rare. There is a particular lack in the formative years and for certain subjects like maths and humanities.

- Barriers to the uptake of collaborative problem-solving include a lack confidence and relevant experience among educators, a lack of training and resources, a level of scepticism and concern (especially around behaviour), as well as system-level barriers like the prevalence of individually driven pupil assessments and competing curriculum priorities.

- In higher education, there is more extensive evidence of the positive impacts of similar approaches, though quality of implementation remains key.

- Research on cognition and observable behaviours may offer ways forward for assessment and teacher observation.

Our exploration of collaborative problem-solving practice has been grounded in existing evidence from:

1. Meta-reviews[2] of the literature about collaboration, problem-solving and collaborative problem-solving.
2. Evaluations, such as that conducted by the OECD.
3. Reports from organisations such as the World Economic Forum and UK Government departments and select committees.

We explore the broader literature about the potential for collaborative learning and problem-solving, before looking at the research into current realities in schools and universities.

The promise of collaboration

The meta-analyses and best evidence syntheses[3] demonstrate that collaborative learning approaches can produce positive effects on pupil achievement, as measured across a range of metrics in the different studies included in the meta-analyses, including standardised attainment tasks. Collaborative group working has also been shown to promote positive attitudes to schooling and to improve the social climate within classrooms. Meta-analyses show that classroom-based studies of collaborative learning consistently show advantages for collaborative group-based learning in classrooms, especially in relation to comparison 'control' classes where the pupils study the same curriculum topics but under traditional, teacher-directed or individual learning practices (see Johnson and Johnson, 2002; Johnson, Johnson and Stanne, 2000; Kyndt et al., 2013; Nunnery, Chappel and Arnold, 2013; Puzio and Collby, 2013; Roseth, Johnson and Johnson, 2008; Slavin, 1989, 2013, 2014; Slavin, Lake, Hanley and Thurston, 2014). Indeed, The Education Endowment Foundation equates the impact of collaborative learning approaches on attainment to an additional five months of schooling.

In addition to evidence about the positive impact of collaborative learning on achievement and attitude, there is also evidence that collaborative learning approaches lead to higher motivation than other traditional approaches to instruction (Johnson, Johnson, Roseth and Shin, 2014). Collaborative learning has also been found to encourage students to be active participants in their own learning (Webb, Troper and Fall, 1995). Student motivation has been linked to higher cognitive engagement and learning outcomes (Ames and Archer, 1988; Pintrich and De Groot, 1990; Pokay and Blumenfeld, 1990). As Slavin (2014) discusses, the motivational perspective on collaborative learning emphasises that motivation to engage in a task is fundamental to learning and is likely to be the driving force behind cognitive processes, involved in learning, for example in resolving conflict. Collaborative learning situations in which students care about the group and the individuals within it lead to engagement with the task and better learning outcomes.

The promise of problem-solving

When we defined problem-solving, we referred to work by Hattie (2009). The research conducted by Hattie involved a detailed analysis of over 800 meta-analyses, each of which provided evidence about the impact on student achievement of a particular intervention. Hattie ranked all the interventions according to an effect size metric that he had created expressly for the purpose. In this way Hattie was able to identify the interventions for which there was evidence of the greatest impact. He also identified six categories of influence that contribute to learning: the student, the home, the school, the curricula, the teacher, and teaching and learning approaches. Hattie evaluated the specific innovations and influences that had the greatest impact on student learning outcomes. He concluded that the key to positively influencing learning outcomes was to make teaching and learning 'visible', which means that teaching must be visible to the learner and that learning must be visible to the teacher. He identified the teaching strategies that are most effective in achieving this visibility and therefore are the most effective at impacting on student achievement. One of four factors that contributed to the effectiveness of a teaching strategy was the use of 'directive teaching methods'. These methods include problem-solving teaching, as defined earlier, with an intervention effect size of 0.61, which is .21 higher than the 0.4 that was the average across all the interventions evaluated by Hattie.[4]

There are some meta-reviews of PBL, which showed superiority of PBL versus more traditional teaching methods often with small effect sizes. For instance, Vernon and Blake (1993) found 0.28 intervention effect size in students' clinical performances, Dochy, Segers, Van den Bossche, and Gijbels (2003) found superiority of PBL in knowledge and skill acquisition in their meta-review of tertiary education studies conducted in real-life classrooms, Gijbels, Dochy, Van den Bossche, and Segers (2005) found a positive impact of PBL on understanding of concepts, understanding of the principles that link concepts, and linking of concepts and principles to conditions and procedures for application.

Specific to the focus here on collaborative problem-solving, we consider the few reviews and analyses that examine the effects on performance of collaborative (and cooperative) problem-solving. Specifically Qin, Johnson and Johnson (1995), undertook a meta-analysis of 46 studies undertaken between 1929 and 1993 examining the effect of collaborative versus competitive problem-solving. Collaboration, as opposed to competition, led to superior quality problem-solving, producing an effect size of 0.60.

The practice of collaborative problem-solving

Collaborative problem-solving in schools: current practice

The promise shown by several decades of research contrasts with accounts of collaborative problem-solving in schools today. This is especially marked with younger learners under 12 years of age and in certain subjects like maths and the humanities.

Studies of UK classrooms show that the majority of learning interaction and talk occurs during whole class teaching. While most children are seated with peers (in pairs or groups), it is rare that they actively collaborate in ways that are cognitively enhancing (Baines, Blatchford and Kutnick, 2003; Bennett and Dunne, 1992; Galton, Hargreaves, Comber, Wall and Pell, 1999).

Galton et al., (1980, repeated in Galton et al., 1999) found that while children sat in small groups for the vast majority of time, only ~14 per cent of this time was used for collaborative learning activity. More recent studies in UK schools (ages five to 16 years) reported similar patterns (Baines et al., 2003; Kutnick and Blatchford, 2013), though the level of collaborative activity varied by curriculum area. Students were least likely to be working collaboratively with peers in maths and humanities, and most likely to in science. Similar findings have been reported in other countries (see for instance in the USA, Webb and Palincsar, 1996)

Other studies suggest that on those rare occasions when teachers do attempt collaborative activities, the quality of the group interaction and dialogue can be poor (Bennett, Desforges, Cockburn and Wilkinson, 1984; Galton and Williamson, 1992). It is little wonder that talk between pupils is often perceived by adults as undermining rather than enhancing learning.

OECD TALIS survey findings for 2013 reinforce the rarity of collaborative approaches. TALIS asked teachers to report on the frequency with which their *"Students work in small groups to come up with a joint solution to a problem or task"*. Findings indicate that on average across the 34 countries surveyed, 8 per cent of teachers said that they use small groups in all or nearly all of their lessons, while only 40 per cent said they used them frequently. Again, maths teachers were least likely to promote collaborative work.

Collaborative problem-solving in post-16 education: current practice

Higher education

There is a range of rigorous research about Project-Based Learning (PjBL) that indicates that it can have clear benefits in terms of attainment, particularly long-term knowledge retention and application (see for example, Yew and Goh, 2016). However, as is reflected in the schools sector research, success depends on precise circumstances, in particular how well the tutors, learners and learning tasks have been prepared. For example, a randomised experiment undertaken to test the effectiveness of PBL as part of the major ESRC funded Teaching and Learning Research Programme looked at whether the use of a PBL-based curriculum in a continuing nursing education programme resulted in higher levels of student attainment when compared to a 'traditional curriculum'. The findings indicated mixed results and negative student reactions, which highlights some of the practical difficulties of translating theory into practice.

The effectiveness of Enquiry-Based Learning (EBL) is highlighted in the final self-evaluation produced by the Centre for Excellence in Enquiry-Based Learning (CEEBL) established at Manchester University at the end of its funding period. A meta-analysis was produced, which demonstrated a significant improvement for EBL in comparison to other methods and that EBL is transferable to all disciplines.

However, we found little quantitative data on how prevalent these approaches are in higher education, with a review from HFEA in 2012 confirming:

"In the UK there are very limited data about the distribution and prevalence of these educational [i.e. pedagogical] practices. This is because arrangements for quality assurance, and institutional review and comparison, do not systematically document such evidence. Nor are they (in the main) the focus of the National Student Survey."

Parsons, Hill, Holland and Willis, 2012, p.14

Further education

Although problem-solving and team working are often considered integral to vocational education, there is a lack of research both in terms of its impact and presence. This lack of research in FE is generally recognised as an issue globally (see for example, Amalathas, 2010). According to Professor Lorna Unwin, the only large-scale, independent study of teaching and learning in English FE to date is the ESRC funded Transforming Learning Cultures in Further Education project (2001-2005). Though findings did not cover collaborative problem-solving (James and Biesta, 2007), there are points that are consistent with the learning theories related to collaborative problem-solving. For example, encouraging students to be proactive, creative and innovative in advancing their own learning under the principle of 'maximising student agency'.

Apprenticeships

Apprenticeships are a growing part of post-16 education in the UK and the existing Apprenticeship Standards in England require covering generic skills such as *"personal learning and thinking skills"*. These fall under six groups: independent enquiry; creative thinking; reflective learning; team working; self-management; and effective participation. Though there is a lot of guidance for providers for audit purposes to show skills descriptors have been 'achieved', there is little on how they can be learnt effectively. One exception to this is a set of simple resources developed by Learning Southwest and posted on the Excellence Gateway. As the new trailblazer models of apprenticeships are introduced, with employers more clearly in the driving seat, personal learning and thinking skills are being dropped as a national requirement. This may create room for more innovative teaching and learning, but currently it is too early to judge the impact. The government's recent Post-16 Skills Plan explicitly recognises that working in a team and solving problems are essential in a 21st century workplace and have asked the Institute for Apprenticeships to work with employers to articulate a common set of transferable workplace skills which could apply across all technical routes and not just to apprenticeships.

Barriers to collaborative problem-solving in education

The following barriers to implementing the widespread take-up of collaborative problem-solving, have been identified.

1. There is a disparity between collaborative problem-solving and the prevailing exam driven education system and curriculum.
2. Collaborative problem-solving is not easy for teachers with busy workloads and high-risk demands of their time and skills.
3. Teachers can be sceptical about the benefits of collaborative problem-solving. Teachers report loss of control, increased disruption and off-task behaviour as the main reasons for avoiding collaborative problem-solving and learning in the classroom (Cohen, 1994).
4. Teachers have little training or confidence in undertaking collaborative learning within their classrooms (Kutnick, Blatchford and Baines, 2005).
5. Students may lack collaborative problem-solving skills and there is uncertainty about the capacity of students to work together (Lewis and Cowie, 1993).
6. Students have concerns about collaborative problem-solving: working with peers can be a risky and emotionally stressful experience, which may result in squabbles, enduring conflicts and public embarrassment (Järvenoja, Järvelä, Baker, Andriessen and Järvelä, 2013) and some children may not like working with others.

A note on cognition and assessment

It is also worth looking at research on mechanisms through which collaborative learning may influence cognition and support deeper learning. These are more observable features and therefore may be useful in developing ways to assess collaborative learning. They include pupils demonstrating ability to:

1. **Articulate, clarify and explain their thinking** (Webb et al., 1995).
2. **Re-structure, clarify and in the process strengthen their own understanding and ideas** to develop their awareness of what they know and what they do not know (Cooper, 1999; Howe, Tolmie, Anderson and Mackenzie, 1992).
3. **Adjust their explanations** when presenting their thinking, which requires that they can also estimate others' understandings.
4. **Listen to ideas and explanations from others -** this may lead listeners to develop understanding in areas that are missing from their own knowledge.
5. **Elaborate and internalise** their new understanding as they process the ideas they hear about from others (Damon, 1984; Wertsch and Stone, 1999).
6. **Actively engage in the construction of ideas and thinking as part of the co-construction of understandings and solutions** (Coleman, 1998; Hatano and Inagaki, 1991; Hogan and Tudge, 1999; Webb and Palincsar, 1996).
7. **Resolve conflicts and respond to challenges by providing complex explanations, counter evidence and counter arguments** (Baines, Rubie-Davies and Blatchford, 2009; Doise and Mugny, 1984; Howe and Tolmie, 1998; Mercer, 1995).
8. **Develop new understandings** to resolve the internal cognitive conflict that arises from discrepancies in the conceptual understanding of others (Doise and Mugny, 1979; Howe, 2009).

Section Three: Collaborative problem-solving and the future of work

- Technology-driven automation of jobs, and other trends, such as demographic change, are transforming the labour market conditions across the globe.

- In the UK, government has already highlighted the future importance of so-called 21st century skills. Though there is no agreed definition of these skills, collaboration and problem-solving both feature significantly in this discussion.

- The impact of these trends on the labour market has significant implications for education, though Nesta research suggests the teaching workforce is safe from automation. Indeed, changes may mean less teacher time is spent on routine tasks and more on creative and social aspects of the profession.

Many OECD countries have serious concerns about the sluggish growth in the productivity across the workforce. None more so than the UK, where productivity growth is flagging in comparison to other G7 nations. These concerns are both constituted and complicated by the way in which automation and other trends are transforming the workplace. The impact of these trends on key sectors of the UK economy is unequal. Take the manufacturing industry for instance. The Davos World Economic Forum identify pervasive shifts as a result of robotics, making this sector the main theme for its 2016 research Mastering the Fourth Industrial Revolution.

In response to the changing nature of employment the UK Government's Productivity Plan, *Fixing the Foundations*, highlights the important role of so-called 21st century skills. As an umbrella term for an array of skills, attributes and behaviours 21st century skills includes but is not limited to, the abilities to problem-solve, communicate effectively, and work in teams. These skills are essential for current work environments and are likely to be a key requirement of future education and training in the UK. For example, the World Economic Forum has proposed 16 skills - these include: collaboration as well as critical thinking and problem-solving. As already noted, a recent report from the UK Institute of Directors stressed the need for schools to move away from the skills that are easiest to teach and test, because these are also the easiest to automate and therefore the least likely to be in demand in the workplace.

Changes to the skills, competencies and knowledge needs of the workforce will not be globally uniform, but will have ramifications for the structure and delivery of education in a multitude of ways, including:

1. **What is taught in schools and beyond**. The teaching and training of students now and in the future will need to deliver high quality subject knowledge and, in addition, the so-called 21st century skills, such as collaborative problem-solving, negotiation, socio-emotional intelligence, knowledge synthesis and probably AI. The nature of these skills will change as the needs of the workplace do, meaning that people will need to undertake lifelong learning if they are to maintain their employability and their contribution to the country's productivity.
2. **The shape of the assessment system**. The education system will need to move away from its emphasis on a stop and test approach that can only assess the routine cognitive skills that are easy to automate and are likely to be the least in demand in the workplace. New forms of assessment that target skills, such as collaborative problem-solving will need to be developed and this is likely to involve the use of data harvested from teaching and learning interactions through and with technology, and the use of increasingly sophisticated and artificially intelligent learning analytics.
3. **Teachers may have and need more time to use their 'uniquely human' skills**. Research by Nesta (2015)[5] indicates that it is unlikely that teachers' jobs will be replaced by automation due to the high levels of social skills used, such as persuasion and negotiation. However, what is highly likely is that parts of their jobs will be augmented by increasing use of technology. Education technology may help with delivery of collaborative tasks (e.g. facilitating knowledge sharing and communication) and may free teachers from routine, time-consuming tasks, allowing them to devote more of their currently squeezed time to creative and social aspects of education.

Section Four: Innovative examples of collaborative problem-solving in education

- We searched for innovative current practice in schools, using a range of primary and secondary research methods, including a teacher survey. Results were then ranked by experts employing comparative judgement methods, using an original CPS taxonomy.

- We found fewer high quality examples than we had hoped for, but where identifiable, good practice often shared common features, such as explicitly targeted development of social skills, teacher-led reflection and active monitoring of the group's progress.

- Some case studies, in particular the SPRinG Project, offer useful insights for schools.

- Practitioner interviews suggest more aspects of collaborative problem-solving exist within problem-solving or groupwork focused programmes. Further research is needed into whether CPS elements in aligned programmes can be 'uncovered'.

The results from our study of the literature illustrate how difficulties can occur when it comes to translating theory into practice. In truth there is less collaborative problem-solving happening in educational institutions than the positive findings from the research evidence might lead one to expect.

A good example of this is The Education Endowment Foundation's (EEF) *Teaching and Learning Toolkit*. It is a summary of education research on teaching five to 16 year olds and lists collaborative learning as the fourth most effective intervention out of a total of 34. However, in spite of this there is little mention of collaborative learning or collaborative problem-solving in any of the 100-plus projects that have been funded by EEF.

It seems that even when we know that there is evidence to support a particular educational intervention, that intervention is not necessarily implemented. The EEF *Teaching and Learning Toolkit* narrative does note that collaborative learning requires planning and structure if the benefits are to be reaped, and perhaps this is part of the reason for its underrepresentation within classrooms, seminar rooms and online. More support in implementation may be lacking for schools and teachers.

The poor link between research evidence and practical action with respect to collaborative problem-solving can also be found in the researchED community. ResearchED is:

"A grassroots, teacher-led organisation aimed at improving research literacy in the educational communities, dismantling myths in education, getting the best research where it is needed most, and providing a platform for educators, academics, and all other parties to meet and discuss what does and doesn't work in the great project of raising our children."

www.workingoutwhatworks.com

ResearchED provides video resources, ideas sheets for key educational topics, events, and news about research findings. We found some excellent resources on the researchED website, but none of them were about collaborative learning or more specifically collaborative problem-solving.

In an attempt to fill in this gap we did our own review of examples of collaborative problem-solving in practice, for which we used a range of exploratory tools, including:

1. A survey of teachers who use the TES Global marketplace (www.tesglobal.com). This yielded 16 examples of collaborative problem-solving in use in education.
2. Twitter searches for tweets about collaborative problem-solving. This yielded many references but no explicit examples of collaborative problem-solving in use in education.
3. Organisations who connect research and practice, such as the Education Endowment Foundation and researchED. This yielded no examples of collaborative problem-solving in use in education.
4. Educator blogs: we searched the blogs identified by Rob Coe as being the top ten educational blogs (http://cem.org/blog/what-is-worth-reading-for-teachers-interested-in-research) and this yielded no examples of collaborative problem-solving in use in education, except with respect to teachers, schools and organisations collaborating with each other.
5. Consultation with our project expert panel, team knowledge and internet searches. This yielded examples of collaborative problem-solving in use in education.

In total we identified 80 examples of collaborative problem-solving practice within education. We then developed a taxonomy to help us describe and classify different examples, to systematise the field and provide a language with which to talk about these practices and finally to identify the areas where collaborative problem-solving could be further developed through practical work.

The collaborative problem-solving taxonomy

The taxonomy we developed was based upon the results of the literature review work discussed in Section Two (see Figure 3). A full explanation of the taxonomy can be found in the Appendix.

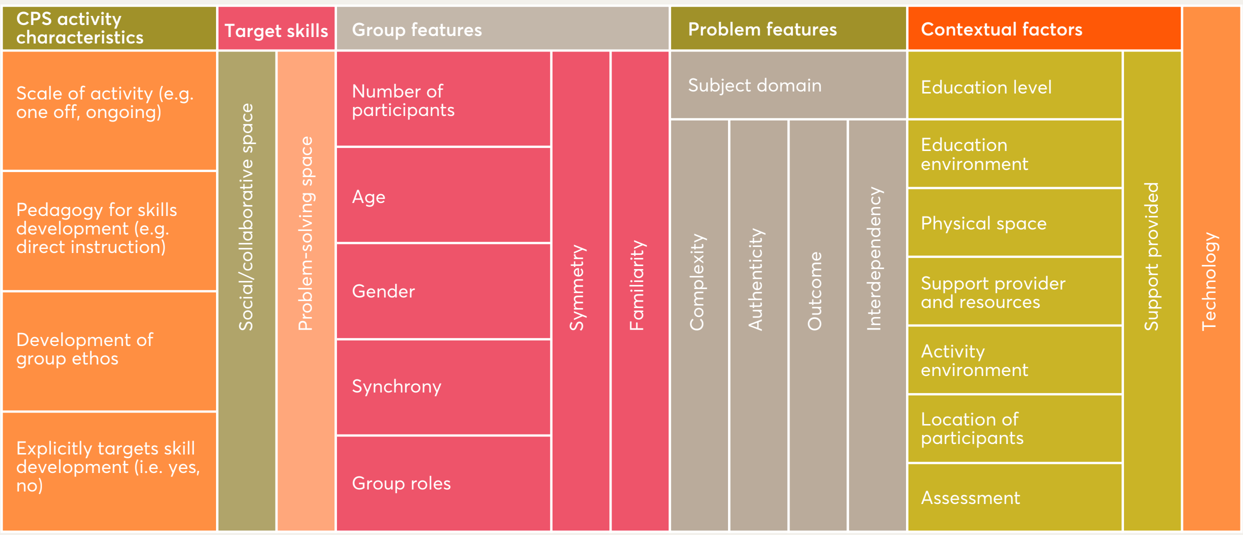
The aims of the taxonomy that we have created are to:

- **Describe and classify** different types and examples of collaborative problem-solving in practice.
- **Systematise** the collaborative problem-solving in practice field, and to help others understand its breadth and complexity.
- **Provide a language** that can be used to search for and talk about collaborative problem-solving in practice.
- **Identify future focus** for Nesta and others, based on observed clusters (or lack) of activity or good evidence of impact.

The taxonomy (illustrated below) has six non-hierarchical, interconnected domains:

- **CPS activity characteristics**: this includes the scale of activity (e.g. one-off or ongoing) and whether (and how) activities develop skills and group ethos.
- **Target skills**, i.e. does the activity target social skills (e.g. ability to negotiate, articulate) or problem-solving skills (e.g. ability to identify facts, generate hypotheses).
- **Group features** including straightforward aspects like gender and age, to the extent that participants share knowledge (symmetry) or are used to working with one another (familiarity).
- **Problem features**: this ranges from the subject (e.g. maths, science), to the extent it could be considered a 'real-world' problem (authenticity) or open or closed-ended (outcome).
- **Contextual factors** ranging from the physical space the task is set in, to participant's level of education.
- **Technology**: how and to what extent technology was used to support CPS tasks.

Figure 3: Taxonomy for collaborative problem-solving



Using comparative judgement to identify innovative collaborative problem-solving

We used the taxonomy to describe our 80 examples of collaborative problem-solving in practice. Each collaborative problem-solving example was described by a brief narrative and an ID card with a unique number, that summarised the example with reference to the taxonomy. More details on this process can be found in the Appendix.

Twenty-five members from our panel of experts (who all come from a variety of different fields) then took part in an online Adaptive Comparative Judgement (ACJ) exercise. The ACJ process rank ordered the examples in terms of the experts' opinions about which of these examples were the most innovative.

The practice examples that were most highly rated by experts had certain common features. For instance, the top five examples:

- **Explicitly targeted the development of social skills**, and two used teacher-led reflection.
- **Monitored the group** process, and one also assessed individuals.
- Involved groups of **mixed gender** and **mixed ability** students acting synchronously. Two of the examples had students who were **well acquainted working together** and one (the activity that was most highly ranked) involved students who were not well acquainted with working together.
- Covered a wide range of features from subject area to **authenticity and complexity**, although none were low-complexity problems.
- **Took place in formal classrooms** and all involved participants in the same physical space who were taking actions in the real world.

Comments made about highly rated examples included, for instance:

"It offers a rich variety of collaborative tasks from creating games to introducing them to pre-school pupils. The acts of agreeing the nature of the games created, creating the games and then working together to describe the games all have the potential for powerful learning."

And for the top rated practice example, experts commented:

"Risky exercise, but has the potential to produce innovative means of addressing the difficult problem of getting learners to reflect on their characteristics."

"Liked this a lot. Good use of teacher observations to develop pupil's social confidence."

Table 1 illustrates the relative importance of the features associated with high scoring examples. The feature that was most highly ranked by experts was monitoring the collaborative problem-solving process (although this did not necessarily mean formally assessing it). The use of technology was also highly rated as was the development of both social and problem-solving skills, and whether the activity provided students with an opportunity and guidance for reflection.

Table 1: Important features in high scoring examples of collaborative problem-solving

	Categories relative importance order	Relative importance size
1	Context: Assessment. Collaborative problem-solving not formally assessed, but the process is monitored	56.4
2	Technology: technology is employed for Collaborative problem-solving	32.7
3	Abilities: Development of skills explicitly targeted in both social and problem-solving domain	28
4	Characteristics: Explicit development of abilities in the form of teacher-led reflection	25.5
5	Characteristics: Explicit development of group-led reflection	23.7
6	Context: Assessment collaborative problem-solving is formally assessed individually	19.3
7	Characteristics: Group ethos addressed as part of the CPS activity	7
8	Abilities: Development of skills targeted in the social domain	3.5

Note: As judged by experts through the comparative judgement exercise.

The three collaborative problem-solving activities that were ranked lowest by the expert panel also had certain common features:

- No explicit focus on social or problem-solving skill development.
- Activity took place in secondary or tertiary education and all three examples involved learners working in the same physical space.
- The focus for evaluation and assessment or monitoring was only on the individual learner.

The reasons experts gave for not selecting practice examples as being both innovative and effective were often about the:

- Lack of interdependence of students.
- Lack of support provided to students for their development of social and problem-solving skills.
- Inappropriateness of the problem tasks provided for students. For example, the task could be completed individually with no need for collaborative problem-solving.
- Lack of opportunities for interactions and discussion among students.

The results of the ACJ process demonstrate that our expert panel was consistent about the aspects of collaborative problem-solving that they valued. They saw it as important that the activities explicitly targeted the development of social skills, and/or problem-solving skills. Problems needed to require that learners engaged in collaboration, because they could not solve the problem alone. Important contextual factors were those that provided opportunities for individual learners to interact and engage in discussion. It was also important for the group process itself to be monitored, even if it was not formally evaluated or assessed.

Further examples and case studies

Following the comparative judgement exercise, we broadened our search terms and conducted brief exploratory research with teachers and educators into programmes and activities related to collaborative problem-solving. These discussions raised the question are aspects of collaborative problem-solving already present in schools and programmes, albeit underdeveloped or unacknowledged?

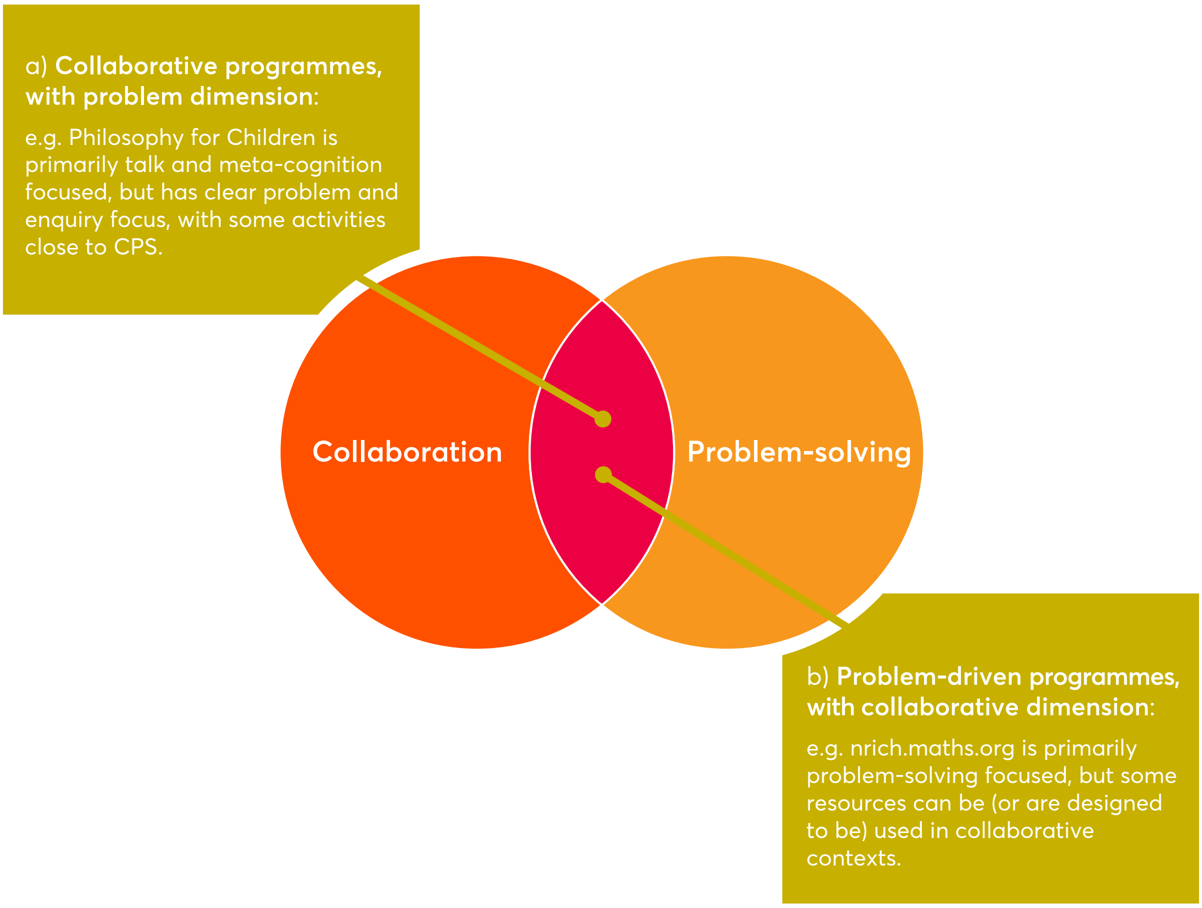
Further research is needed, but below are some examples of programmes or activities mentioned by practitioners and interviewees when discussing collaborative problem-solving:

- **Nrich.maths.org**, a maths education website with millions of visitors each year, set up by Cambridge University. Nrich focuses on mathematical problem-solving, not collaboration, but in practice resources are often used by schools in groups and they recently launched an early years and primary focused set of problems called Being Collaborative.
- Talk and meta-cognition focused programmes like **Thinking, Talking, Doing Science, Thinking Together** and **Philosophy for Children**. Although these do not meet all the criteria for collaborative problem-solving, there are significant overlaps, with both sharing strong elements of enquiry and problem-focus, as well as using pupils talking, reasoning and working together to develop thinking.
- Individual school practice or action research, with a focus on related terms, in particular around problem-solving or ideas of self-regulation or resilience. For example, **Harris Academy Battersea** is currently trialling a card-based approach to scaffolding group problem-solving, building on one teacher's masters research into 'self-regulated learning during collaborative discussion' (see page 32 of this report).

- Out-of-school activities or corporate initiatives, particularly in the Digital Skills space with organisations like **Apps for Good**, where students work together collaboratively to develop an app to solve a social problem. Their focus is on computational skills and creativity, but there is a clear aspect of collaborative problem-solving. Or another example might be **The LEGO Foundation's** 'Six Bricks' initiative - a play-based learning approach which encourages the use of collaboration, problem-solving and language skills in early years.

With this in mind, we can imagine collaborative problem-solving alongside other skills, with programmes cutting across categories rather than allocated in a binary fashion to either one or the other. Further research is needed on whether the similarities in these concepts is meaningful or superficial.

Figure 4: Moving beyond a binary view of collaborative problem-solving



Case study 1

The SPRinG Programme

The SPRinG programme (see Baines, Blatchford and Kutnick, 2016)[6] aimed to address the gap between the potential of group work to influence attainment and learning, and the limited use of group work in schools, on the other. The project worked with teachers to develop a programme of classroom practices and pupil skills training to improve the effectiveness of collaborative group work across Key Stages 1-3. Ultimately the approach aimed to encourage a strategic approach to working together that emphasises that pupils take responsibility for their own interactions and learning and working together. It was structured around four key principles for facilitating collaboration:

1. Careful attention to the **physical and social organisation** of the classroom and groups (e.g. taking account of the number, size, stability and composition of groups).
2. Development of **pupils' group-working skills** (based upon an inclusive relational approach, working with all children in a class) through activities to develop social, communication and advanced group-working skills.
3. The creation and structuring of **challenging tasks** that legitimise collaborative group work.
4. The **supportive involvement of teachers** and other adults in guiding, facilitating and monitoring collaborative group work.

Quantitative and qualitative research findings showed that engaging in the SPRinG group-work programme had a positive effect on all pupils. Group work led to marked gains in attainment and learning, greater levels of active classroom engagement and sustained collaborative discussions, and the clear sense among pupils and teachers that working collaboratively in groups was a positive classroom experience. The SPRinG programme led to observed changes in pupil behaviour and interaction that explain changes in attainment and learning (Blatchford et al., 2006). Teachers also reported positive effects for both their practice and classroom management and for their students. However, there were areas of challenge that still remained, particularly in relation to the inclusion of children with special educational needs (Baines, Blatchford and Webster, 2015). Based on the success of SPRinG, this approach has been taken up in a number of different contexts, internationally and in urban and rural areas (see Galton, Hargreaves and Pell, 2009; Kutnick et al., 2013).

In addition to a useful handbook for schools, the programme is currently being developed as a school improvement and knowledge exchange programme for senior leaders, teachers and TAs.

Case study 2

The PELARS Project

The PELARS project (www.pelars.eu) explores collaborative problem-solving through open-ended design tasks involving physical computing in STEM education with learners aged 14 years and over. The aim is to develop learning analytics tools for student reflection and for teachers to monitor and support complex, practice-based collaborative problem-solving. It used a workstation with sophisticated computer sensors to automatically collect data, as well as tools for students to document their experience of planning, building and reflection (including camera snapshots and buttons to report sentiment). In addition to these, observers (e.g. a teacher, researcher) notes and codes activity via an observation tool with a collaboration and problem-solving dimension.

The machine then generates visualisations of student activity, in particular the amount of time (or repeated attempts) students spend before reaching a solution or stopping work; the type, complexity and variety of alternative logic or the set of components they used to reach their solutions (Cukurova, Mavrikis and Luckin, 2017).

Figure 5: Visualisation of students' practice-based activities in PELARS System

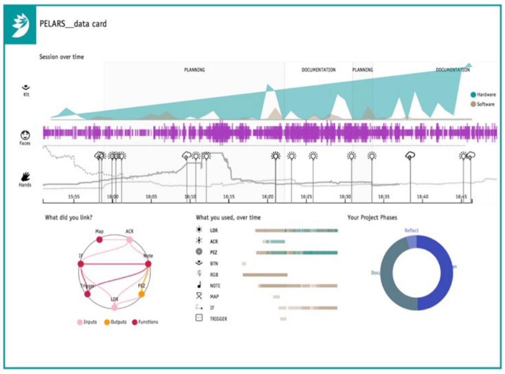
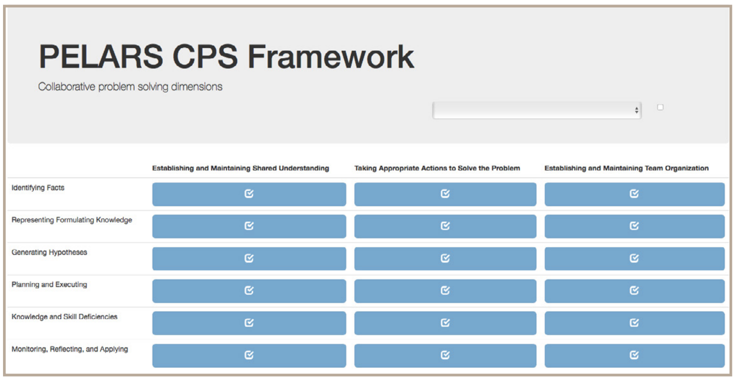


Figure 6: The PELARS observation framework



Preliminary results suggest that students with more experience of working together appear to spend more time 'identifying facts' and 'establishing and maintaining shared understanding', while novices spend more of their time 'taking actions to solve the problem' (Cukurova, Avramides, Luckin and Mavrikis, 2016). These comparisons of learner behaviour can help educators identify which behaviours to encourage to support the collaborative problem-solving process in various teaching contexts. New technologies such as PELARS may offer further opportunities to better understand and support complex learning processes, such as collaborative problem-solving.

Case study 3

Self-regulation and collaborative discussion

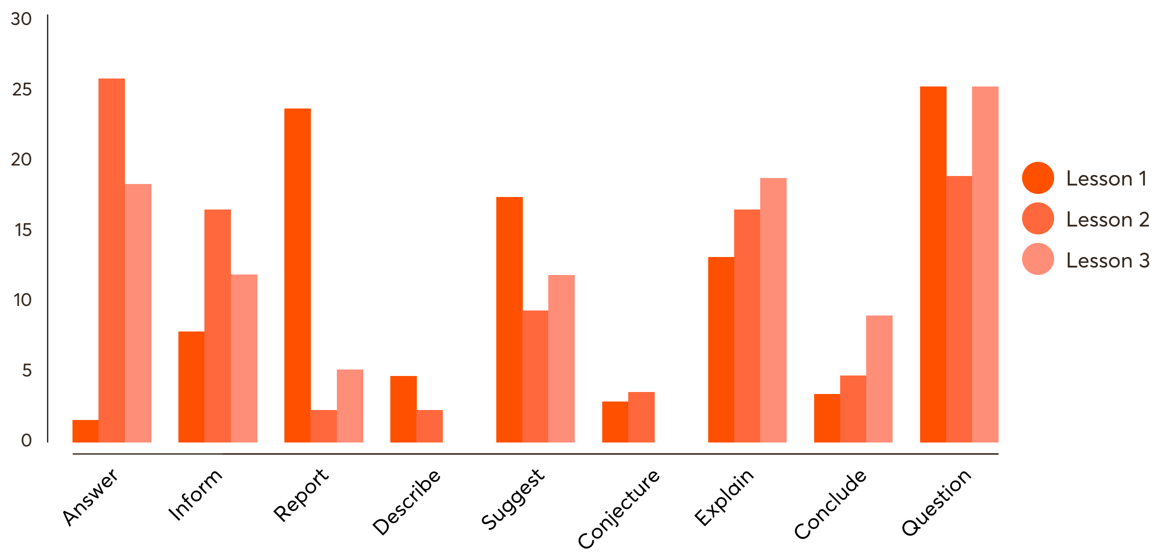
Tom Harriott's thesis[7] concentrated on examining the effectiveness of collaborative discussion as a tool to promote and foster self-regulated learning in students. It is interesting because, unlike the other case studies, it is action research taking place in a real school context. Tom worked with a small number of students from a Year nine class, studying triple science GCSE at a large, mixed Inner London comprehensive,[8] and recorded discussion tasks across three lessons each introduced by an open-ended inquiry based question, such as *"Are biofuels a positive solution to the fossil fuel issue?"*

Tom put a range of mechanisms in place to promote high-level collaborative discussion, including requiring students to share all relevant information, to respect and consider each other's ideas and to seek group consensus before finalising decisions. He then coded different types of utterance to determine levels of self-regulation.

Analysis of the coding showed a decrease in the reliance on stimulus material, and an increase in the number of explanations and conclusions given by students. Although the proportion of questions did not change, the proportion of answers increased significantly [see Figure 7 below]. The coding together with the transcripts and observation suggested quality collaborative discussion taking place, and a marked improvement as the sequence of lessons progressed.

Interestingly, Tom also found that group dynamics affected individual contributions. Some students consistently regulated themselves, whereas others generally allowed themselves to be regulated by others (for example, they might be dominated in some conversations). This pattern tended to become more embedded as lessons progressed.

Figure 7:



Section Five: How can we support effective collaborative problem-solving?

- There is not a 'one size fits all' solution. Schools must identify which aspects are most important, but also practical in their settings, and then implement accordingly.

- We recommend schools think about making changes in terms of three areas: the task and learners, the teacher and training, and senior leadership and school policy.

- Schools should implement changes gradually and think in terms of degrees, asking is this more collaborative or more problem-solving based than before?

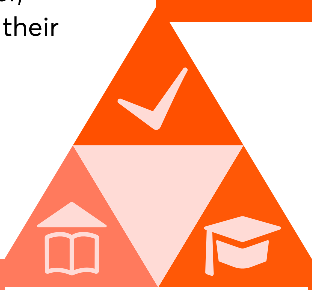
- At a system level, national investment or support for training, lesson resources, guidance and assessment is crucial for long-term improvement.

Literature reviews and meta-analyses can give the impression that you can isolate particular variables and then apply them in new contexts. In practice, variables are interconnected and the context in which they are applied (and were studied) is key. Ultimately teachers and school leaders need to apply findings in a strategic manner, identifying which areas are useful for their students and setting.

We suggest three main areas for consideration:

1. Task design

- Carefully consider what knowledge is being introduced or applied.
- Balance interdependence with individual accountability.
- Structure task to promote right behaviours (e.g. reflection time, roles).



2. Teaching style

- Hint and ask pertinent questions, without giving the answer.
- Monitor group and be change to willing to change them or handpick members.
- Balance support and freedom.
- Be patient: it may take time to embed.

3. Leadership support

- Give staff time to design, embed and improve.
- Familiarise with research, be an advocate externally (e.g. Ofsted, parents).
- Monitor, evaluate progress and intervene as necessary.

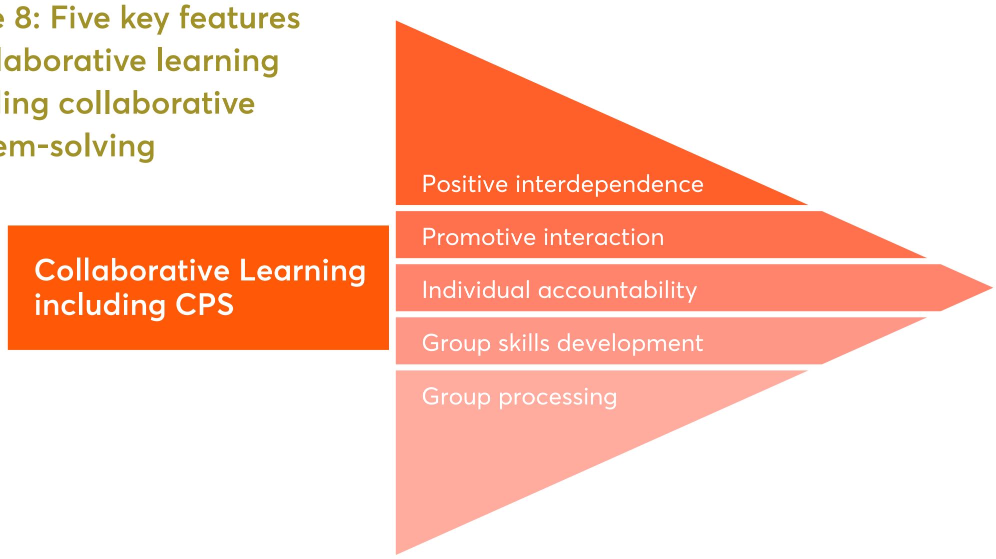
1. Task design

Typically effective collaborative learning in schools includes a high level of structure, with careful thought on what (and how) knowledge is being introduced or applied. Learning tasks with clear roles/protocol, such that group members have a clear responsibility and are able to assist other members of the group.

Early research by Deutsch (1949) highlights positive interdependence and promotive interaction as central in this structure. More recently, Slavin (2015) argued that positive interdependence and individual accountability are the two most important elements. Broadly speaking, many recognise a set of five essential features for successful collaborative learning:

1. **Positive interdependence**: This means that the task cannot be completed by one person alone. Groups members must synchronise their efforts.
2. **Promotive interaction**: Members are willing to support each other to complete the task.
3. **Individually accountable**: Students must undertake their share of the work and feel responsible for the group's success.
4. **Interpersonal and group skills need to be developed/supported**: We cannot assume students naturally have (or will use) high-level collaboration skills.
5. **Group processing**: Members reflect on the quality of their working relationship and seek to improve it through personal and joint effort.

Figure 8: Five key features of collaborative learning including collaborative problem-solving



The relative importance of these is debated and it may be that teachers focus on one aspect initially. How these principles are put into practice can also vary, for example:

- **Individual accountability** could be achieved through individual scores combining to a group score, or just group scores, or purely by developing a sense of trust and responsibility to group success.
- **Positive interdependence** could be achieved simply by stipulating that each participant must be given a minute at the start to share their views, before proceeding with group discussion and agreement. Or, it could be achieved with a complex task where information (or responsibilities) are unequally shared.

To add problem-solving to these collaborative learning features, would mean adding additional criteria that learners must:

- **Retrieve and apply existing knowledge** about both the subject matter and the process of problem-solving.
- **Identify obstacles in the problem**, process information and identify possible (and preferred) goals and associated actions.
- **Establish a joint understanding of the problem** and then negotiate, through processes of interthinking and argumentation, and then action, to the solution.

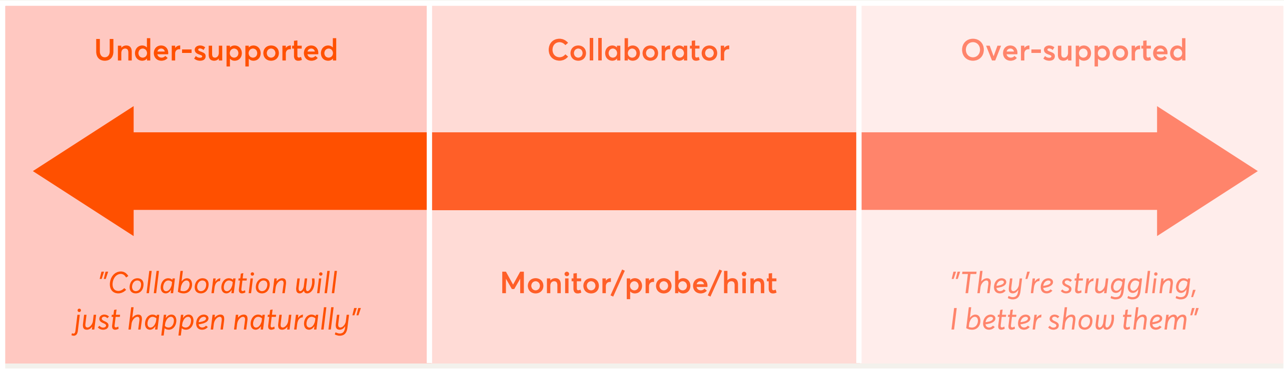
Finally, it is worth considering this report's taxonomy and the features ranked highly by our expert panel. The most influential feature was that the teacher pays attention and evaluates the group CPS process - i.e. simply by actively considering, by being aware of what the group is doing, teachers can significantly improve the quality of a CPS activity. Also highly ranked was use of technology, explicit development of students' social and problem solving skills, teacher-led reflection and group-led reflection - the latter three of these are easy and cheap to implement in most lessons.

2. Teaching style

The success of collaborative problem-solving depends on how teachers strategically organise, set up tasks, engage with, and support groups. But it is a difficult balancing act.

At one end, teachers can incorrectly assume that collaboration will 'just happen' by putting pupils into groups. At the other end, there is the opposite risk that a teacher adopts an approach that is too directive, dominating, and that undermines the value of the group to detrimental effect (Webb, 2009). It is difficult for adults to resist taking over the group when they begin to struggle with a problem.

Figure 9: A balancing act



Evidence suggests that there is a middle way, where teachers monitor group interaction, ask pertinent or open-ended questions that help students reflect on their own views and those of others (Galton and Williamson, 1992). Teachers can engage in discussions, but with a view to probe, challenge and present alternative perspectives. In many ways, this sees them acting more as collaborators, leading by example.

For most teachers, this requires practice, reflection and training, before they feel confident strategically setting up, managing and supporting good collaborative learning (Gillies and Boyle, 2010; Kutnick, et al., 2013).

Behaviour management is another consideration. Collaborative problem-solving activities raise the level of discussion and debate, which in turn can affect classroom noise levels, and lead to conflict and aggression between pupils. We therefore **recommend a gradual introduction of these activities**, with frequent opportunities early on for pupils (and teachers) to reflect and develop the necessary skills of trust, self-control, productive argument and so on. After repeated experiences, students can begin to help learners to take responsibility for their own learning, to seek help and guidance from each other, and to be able to manage disputes and to resolve them amicably through compromise (Baines et al., 2008; Blatchford et al., 2003; Kutnick and Blatchford, 2014; Tolmie, 2013).

Training and practice is just as important for students. Children and young people do not spontaneously engage in high-level collaborative discussion, explanation, and thinking, even when tasks are set up to encourage this (Baines and Howe, 2010; Chinn, O'Donnell and Jinks, 2000; Gillies, 2016; Mercer and Littleton, 2007; Webb, 2009). Recent work suggests regular practice, experience and training in group work helps students get better at working with all kinds of group members, whether high, middle or low attaining, whether friends, acquaintances or strangers, and whether on tasks that are structured to make group members mutually interdependent or not (Kutnick et al., 2013).

Selecting the group: teachers know their classes better and must decide the groups they see fit, but there are interesting findings and practical tips from the SPRinG Project (see case study, page 30). In addition to this, there is some evidence around the benefits of working with friends - a meta-review of studies focusing on children working with friends, as opposed to acquaintances or non-friends, found that when problems were challenging (as opposed to less challenging practice or revision tasks) pairs of friends tended to collaborate together better than non-friends (Zajac and Hartup, 1997). More recent research suggests that this may also interact with gender such that girls who are friends are more likely to engage in productive collaborative problem-solving than either girls who are not friends or boys who are friends (Kutnick and Kington, 2005). Therefore at least initially, it may be worth letting pupils work with those they are close to.

3. Leadership support

None of the suggestions above are possible without senior leadership support. For some this might mean budget for training, or for others it might be planning time. But the crucial factor is that senior leadership actively support the approach. This means they fully understand why they are doing it and what it involves (including evidence on impact, but also challenges) and actively endorse it.

This active support means they are willing to give teachers time to embed practice, to justify and advocate the approach to external visitors (whether governors, or Ofsted), and to accept that good learning may sound and look different from what they're used to.

None of this should be done uncritically - collaborative problem-solving will only have impact if implemented appropriately and this ongoing impact monitored - but this is all the more reason why senior leaders should be actively involved, to ensure the approach is embedded in a way that fits their school.

The school system

All of these school recommendations have a system implication. Though a school can create its own tasks or training, these would benefit from system-level support. This might mean recognising the need for explicit inclusion of collaborative problem-solving guidance and practice in initial teacher training, or support for subject-specific organisations (such as nrich or the NCETM in maths) to create and share good collaborative problem-solving tasks and guidance. Quality Training in particular has a major impact on teacher's ability to lead these activities (Gillies and Boyle, 2010; Kutnick, Blatchford, Baines and Tolmie, 2013).

At a national policy level, recognition of the value of these skills will help leaders. Rather than justifying their investment in the absence of (or face of) curriculum or Ofsted guidance, government or national bodies can play a role in recognising and supporting these approaches.

Longer-term investment and research is needed in other areas, particularly assessment, given its importance in the education system. Though there is growing interest in assessing aspects of problem-solving as part of the national curriculum, there remain significant challenges to assessing the full extent of these skills. Addressing these challenges will take time and sustained investment, research and testing. Following the OECD's lead with their recent Collaborative Problem Solving PISA tests, the UK government could support this agenda by researching and testing ways to assess these skills. In Singapore, a frequent world leader in the PISA education tables, research on this began back in 2015.

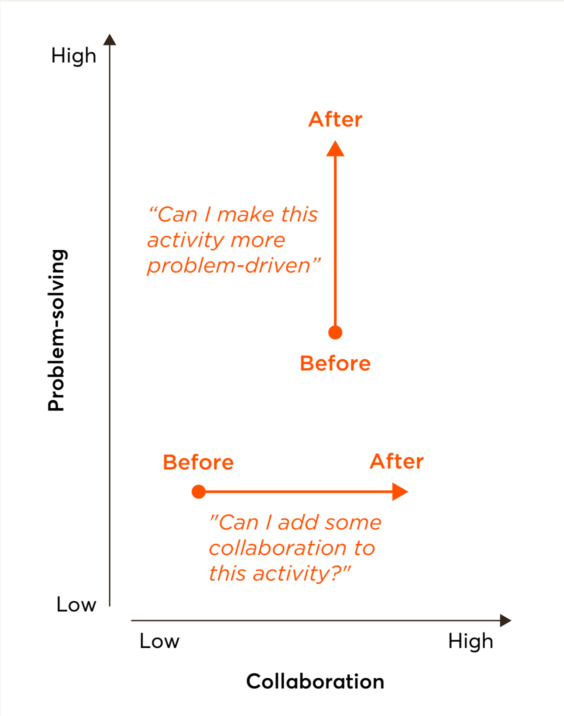
Putting the findings into practice in school

The findings suggest that a gradual and sustained introduction that is tailored to a school setting, will get the best results for teachers and pupils.

From a practical perspective, rather than aiming to achieve 'textbook' collaborative problem-solving in schools and potentially fall short, we would also suggest that teachers:

- Reflect on the features of CPS, then select those that are most important to them, and rephrase them in words that work for their school.
- Consider CPS not as a binary but as a scale, i.e. ask themselves not 'is this activity CPS?' but 'can I make this activity more CPS?

Figure 10: Making learning more CPS, one question at a time



Are your kids collaborating?

To launch our report, we've created an online quiz to help teachers and parents reflect on how they foster collaboration and problem-solving, along with some helpful tips.

www.nesta.org.uk/kids-collaborating

Calling all teachers and parents - are you equipping your kids with the right skills for the future?

The kids are coding. They're building websites and apps, and closing the digital skills gap. So what's the next skills shortage?

As our report suggests the ability to solve problems with others (collaborative problem-solving) will be a crucial skill in the future workplace and, if facilitated properly, can also support academic attainment. This can be done by giving children tasks to solve with friends or other adults too!

Solving problems with others means applying knowledge to real issues through discussion, debate and then making decisions as a group.

But are you helping your children develop these skills?

Section Six: Conclusions and recommendations

There is research evidence that is specific to collaborative problem-solving, with much more being focused on the super category of collaborative learning. We found good evidence to suggest that well designed and managed collaborative problem-solving has a positive impact on learning, including attainment and learner attitude. And that for this to take place, both learners and teachers need relevant knowledge and skills.

Solving problems with others (collaborative problem-solving) is a key skill for the workplace, and its importance is only likely to grow as further automation takes place. Effective collaborative problem-solving does not, however, take place spontaneously but requires design, monitoring and management. We have identified a taxonomy of collaborative problem-solving and associated key (and interrelated) features that are common to effective collaborative problem-solving.

There is a mismatch between the substantial evidence in favour of collaborative problem-solving and learning reported in the literature and the approaches widely used within schools. This is neither preparing students for university nor the workplace. It is exemplified in a quote from a Davos 2016 debate on the Future of Education, where a student from Hong Kong said the current school system produced 'industrialised mass-produced exam geniuses who excel in examinations' but who are 'easily shattered when they face challenges'. We need higher education students and employees to be able to tackle challenges. This involves working effectively with others to solve problems; we don't need exam geniuses who crumble under the pressure of the real world.

The situation in higher education is more positive, but there is insufficient information to know the extent of the effectiveness of the collaborative problem-solving approaches being adopted. Changes associated with the growing emphasis on teaching quality, competition and student choice in national policies, and the introduction of the Teaching Excellence Framework (TEF) in the UK, could enable some more systematic monitoring of teaching practices and encourage further take up of approaches like collaborative problem-solving. The lack of collaborative problem-solving practice reported from FE may well not reflect the real practice within colleges, but without clear data on the teaching approaches adopted within FE it is hard to reach any conclusions.

The future for collaborative problem-solving is not currently as bright as it should be and there is clearly a role for Nesta to play in helping organisations to embrace and reap the potential of collaborative problem-solving. There are, however, significant barriers to adoption; these include the prevalence of individually driven and assessed education systems, the wariness with which many educators and students view collaborative and problem-based learning and the lack of educator and student skills and training. We are glad that this evidence review has helped inform Nesta's practical recommendations below.

Recommendations from Nesta

We conclude that the following five recommendations (and practical ideas) to strengthen opportunities for young people to solve problems together (collaborative problem-solving), both in and outside formal education:

1. **Stimulate production of quality collaborative problem-solving (CPS) resources and training, from primary onwards**

   Most teachers lack the time to design group problem-solving activities or the confidence to use them, even once aware of the benefits. Developing more curriculum-aligned resources and training will help teachers take the first step.

   - Work with subject associations (e.g. NCETM for maths, or The Geographical Association) and publishers to develop a bank of **curriculum-aligned, CPS lesson ideas**, as starting points for teachers to adapt.
   - Work with teacher training providers to develop **subject-specific CPS training modules**, to give teachers knowledge, expertise and confidence.
   - Encourage and share emerging classroom practice through key-stage-specific **CPS innovation prizes**, an **online teacher sharing platform** for classroom-tested resources, as well as awards for action research.

2. **Fund existing, aligned programmes to scale and evaluate impact**

   Aligned programmes offer an opportunity to address the gap between promise and practice at scale, while growing the evidence base around what works and addressing teacher and pupil scepticism:

   - For early-stage or emerging initiatives (e.g. Nrich's 'Being Collaborative' resources), provide **grant funding for pilots** and evaluation. The EEF, for example, could run a funding round focused on collaborative projects.
   - For larger, aligned programmes with good evidence (e.g. Philosophy For Children, SPRinG, Thinking Together), provide grant funding for **scale-up** and for uncovering, **strengthening and measuring** collaborative or problem-solving aspects of their work.

3. **Educate and involve the out-of-school learning sector and volunteer educators**

   While teacher involvement is essential, some of the most receptive audiences are likely to be in non-traditional settings.

   - Open up training and learning events to out-of-school education programmes, so they can test and evaluate collaborative and problem-based aspects of existing programmes, starting with the digital making space.
   - Harness student and community volunteers to power collaborative activities in class or after-school, following the lead of peer and volunteer-powered programmes like Franklin Scholars or The Access Project.
   - Create a coalition of corporates which recognise the value of these skills to embed collaboration and problem-solving into their CSR and volunteering activities.

4. **Develop smarter collaborative problem-solving assessment methods**

   The 2014 national curriculum made a step in the right direction, introducing a problem-solving focus in some subjects, but more can be done.

   - Building on the OECD's PISA collaborative problem-solving assessment (results due 2017), government should begin small-scale, annual assessment trials, to systematically learn what can be measured for both low and high-stakes assessment.

5. **Help higher education organisations and MOOCs to track what works**

   In higher education though, there is more support for these practices, evidence is limited by a lack of cross-sector work and measurement.

   - Contribute to the proposed Teaching Excellence Framework (TEF), TEF assessment and National Student Survey (NSS) to build evidence on prevalence and practice of collaborative problem-solving across the sector.
   - Run learning analytics data pilots into the mechanisms driving good collaboration and problem-solving, working with collaborative MOOCs like Futurelearn or altMBA and mainstream university data systems.

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Appendix

We used the taxonomy to describe our 80 examples of collaborative problem-solving in practice. Each collaborative problem-solving example was described by a brief narrative and an ID card with a unique number, that summarised the example with reference to the taxonomy. However, it was impossible to complete the entire taxonomy for any of the examples, because there was insufficient information available. We therefore summarised as much taxonomic information as possible accepting that there would inevitably be gaps. This enabled us to classify our 80 examples of collaborative problem-solving as illustrated in Table 2.

Table 2: Taxonomy and CPS practice examples

Category feature from taxonomy	Percentage of practice example with this taxonomic feature
Context: Assessment. Collaborative problem-solving is not formally assessed, but the process is monitored	48
Context: Assessment. Collaborative problem-solving is formally assessed at the group level	37
Context: Assessment. Collaborative problem-solving is formally assessed individually	15
Characteristics: Explicit Development of Abilities in the form of Teacher-led reflection	31
Characteristics: Explicit Development of Group-led reflection	10
Characteristics: Group ethos addressed as part of the CPS activity	1
Characteristics: A programme of activities of collaborative problem-solving not just a one-off CPS activity	1
Technology: technology is employed for collaborative problem-solving	24
Abilities: Development of skills explicitly targeted in the social domain	26
Abilities: Development of skills explicitly targeted in both social and problem-solving domain	20
Abilities: Development of skills explicitly targeted in the problem-solving domain	14
Problem Feature: Subject Domain - cross-curricular collaborative problem-solving activity	20
Group Features: Group roles are allocated	18
Group Features: Single gender grouping	1

We then selected 25 members from our panel of experts (who all come from a variety of different fields) to take part in an online Adaptive Comparative Judgement (ACJ) exercise. The ACJ process rank ordered the examples in terms of the experts' opinions about which of these examples were the most innovative

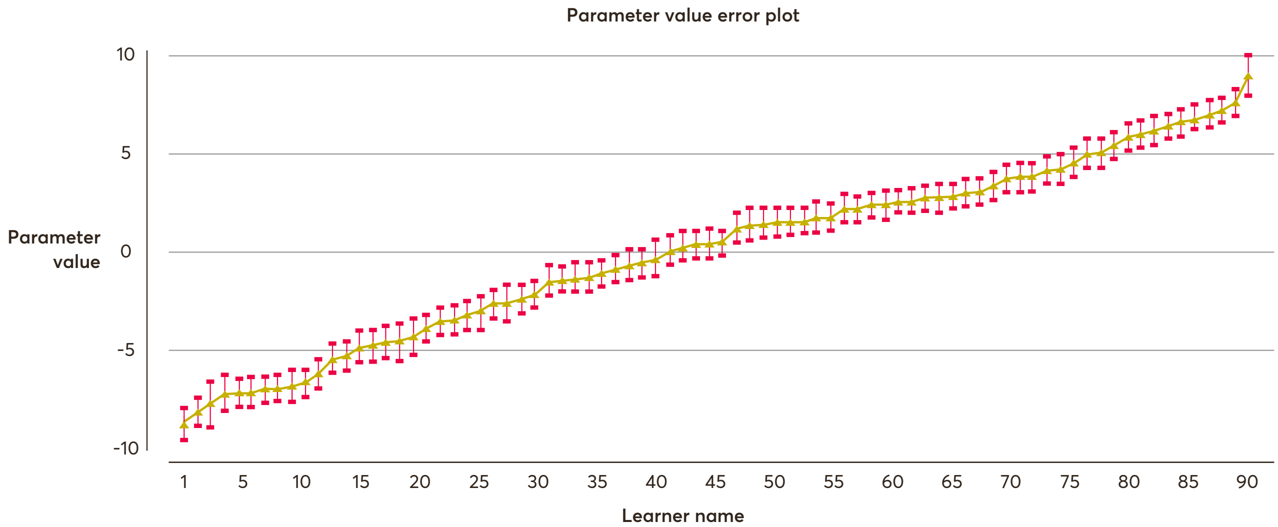
The narrative descriptions and ID cards for all 80 collaborative problem-solving examples were then used for the process. The Appendix contains more information about the ACJ process and includes samples of practice example narrative and ID cards, as well as results. The software used for the process was produced by Digital Assess Ltd and it was available online. The software presented each member of the expert panel with two practice examples side by side simultaneously and asked the expert to pick one of them. The precise instructions we gave to the experts were:

"Please read the examples and compare each of the two examples of CPS that are presented to you and decide which of them is the best example of innovative practice that is likely to be effective for learning."

The first five rounds of the comparisons were non-adaptive 'Swiss Tournament' rounds to create a rough sort. After the fifth round, the software became adaptive and started to present those examples that were closely ranked in the previous round in order to increase the reliability coefficient. At the end of the 14th round the reliability coefficient reached above 0.96.

Figure 11 presents the final ranking of the practice examples. The green triangles represent the practice examples and the red lines are a graphical representation of the certainty that the software has about the placement of each practice example in the rank order after that round of judgment, in this example after round 14. The shorter the line the greater the confidence.

Figure 11: Parameter value error plot



Please note that the graph mentions 'Learner name' as the software is often used to compare student scripts. However, in our case it refers to the practice example number.

The table below provides a glossary for the different factors comprised in each of the six different domains identified in the taxonomy. These are the factors which the expert panel considered when judging examples of innovative current practise of CPS in schools.

N.B. This only included examples which had education as the primary goal and that involved groups of fewer than 30 participants and that is not considered to be purely peer-tutoring.

Table 3: Detailed category information for collaborative problem-solving taxonomy

CPS activity characteristics		
Category feature	Description	Example
Scale of activity	The size of the unit being considered.	Is it a single/one-off activity or part of a programme of interconnected activities?
Explicitly targets skills development	The extent to which participant's abilities are explicitly targeted by the CPS.	Are skills in the social space targeted; are skills in the problem space targeted; skills in both the social and problem space targeted; or are no skills explicitly targeted?
Pedagogy for skills development	The way in which a wide range of abilities are developed separately from the CPS activity.	Adult modelling; adult or group led metacognitive/reflective processing; direct instruction (including coaching).
Development of group ethos	The extent to which the CPS activity led to the development of a group ethos.	Was this addressed through team building activities, group processing or not addressed?
Target skills		
Social/collaborative space	The explicit development of abilities which enable a person to function effectively while interacting with others.	Ability to participate as a member of a group; ability to place oneself in another's position; ability to negotiate; ability to resolve conflict etc.
Problem-solving space	The explicit development of abilities which enable a person to function effectively while working to bring a problem state closer to an aimed state.	Ability to identify facts; ability to represent, formulate, and build knowledge; ability to generate hypotheses; ability to plan and execute actions, ability to identify knowledge and skill deficiencies, ability to reflect on actions.

Group features		
Number of participants	The number of participants forming a group.	n/a
Age	The age distribution of participants forming a group.	Are they in similar or mixed age groups?
Gender	The gender distribution of participants forming a group.	Are they in same or mixed gender groups?
Synchrony	The action timings of participants with respect to each other.	Are participants acting synchronously or asynchronously?
Group roles	The extent to which specialised roles are encouraged and allocated by activity designer.	Are participants placed in subtask role as in jigsaw working or is the group free to plan their own group roles?
Group familiarity	The extent to which participants are used to working with one another as part of a group.	**High**: Participants work in experienced or bonded groups. **Medium**: Acquaintance groups; groups may have worked together before. **Low**: Participants may have never worked together before.
Symmetry in the group	The extent to which participants' share the same level of knowledge and skills related to the problem state.	**High**: All participants have more or less the same level of knowledge, skills and attainment. **Medium**: Most participants have more or less the same level of knowledge. **Low**: Some/none of the participants share more or less the same level.
Problem features		
Subject domain	Subject domain within the educational context.	Science, Technology, Engineering and Maths; Social Sciences, Literacy, Arts and Humanities; cross curricular.
Intended complexity	How complex the problem is. Proximity of the problem state to the aimed state (as judged by an expert/teacher).	**High**: Distance between the problem state and the aimed state high. **Medium**: Distance between the problem state and the aimed state is medium. **Low**: Distance between the aimed state is low.
Authenticity	The proximity of the problem to a real-world problem.	**High**: Participants are dealing with a real-world problem. **Medium**: Dealing with a fabricated problem representing a real-world problem. **Low**: Dealing with a fabricated problem, which does not represent any real-world problem.

Outcome	Extent to which the problem is open-ended.	**High**: Single solution/closed problem. **Medium**: Multiple/best-fit problem. **Low**: Open/no single solution.
Interdependency	Extent to which the design characteristics lead to social interdependence.	**High**: Most lead to social interdependence. **Medium**: Some lead to social interdependence. **Low**: A few/none lead to social interdependence.
Environmental factors		
Education levels	Level of education of the participants.	Primary school, secondary school, tertiary education or mixed education levels.
Education environment	Physical space the activity takes place in.	Does it take place in a classroom, fieldwork, school laboratories etc.?
Physical space/ context	How is the space utilised within that environment?	Is the flexible use of furniture/space for participant interaction explicitly considered and used or not?
Activity environment	The interaction space.	Digital environment, real world using physical models or real world state.
Location of participants	The location of the participants in respect to each other.	Are they in the same or different physical environment?
Assessment	The way in which participants are assessed.	Are participants assessed individually, as a group, monitored but not assessed or neither monitored nor assessed?
Identity of support provider	Who is providing the support for the activity?	Are they a trained expert, teaching assistant or learning support assistant, digital tool/context, physical tool/context?
Resources and tools	The tools and resources used for the CPS activity.	Are only digital tools/resources used, only physical tools/resources used or both digital and physical resources used?
Support provided	Amount and quality of support provided to participants with digital tools and/or adult support.	**High**: Scaffolded support for both the social and the problem space is provided. **Medium**: Provided either in the social or the problem space. **Low**: Not provided for the social or the problem space.
Technology		
This category looked at the use of different types of technology used to support collaborative problem-solving. Technology can play the role of a tool to support collaboration, the means through which collaborators can communicate, a way of representing the knowledge and skills to be learnt or it can be embedded within the environment. We have chosen not to sub-divide the technology domain in order to recognise the primary importance of the learning process and its participants and context. The technology should be subsidiary.		

Expert Panel

Ayesha Ahmed – University of Cambridge

Britte Cheng – SRI (Stanford Research Institute)

Anne Chowne – Teacher trainer, educator, researcher

Caroline Creaby – Headteacher Sandringham School

Charles Crook – University of Nottingham

Cynthia D'angelo – SRI (Stanford Research Institute)

Monique Darrell – Primary school teacher

Geraldine Davies – UCL Academy

Helen Drury – Mathematics Mastery

Chris Gerry – Headteacher theskillslab

Patrick Griffin – University of Melbourne

Carl Hendrick – Wellington College

Kim Issroff – Blue Yonder

Ann Jones – Open University

Elizabeth Koh – NIE Singapore

Peter Kutnick – Kings College London

Cheekit Looi – National institute of Education Singapore

Stella Mbubaegbu – Highbury College

Neil Mercer – University of Cambridge

Jennie O'Donovan – Nodebook

Noreen Richardson – Christ the King Sixth Form College

Nikol Rummel – Ruhr University of Bochum

Tony Russell – Teacher, researcher, teacher trainer

Piers Saunders – Secondary school teacher, teacher trainer

Eileen Scanlon – Open University

Cindy Hmelo-Silver – Indiana University

Roger Turner – Lightspeed Technology's Flexcat classroom

Lorna Unwin – UCL Institute of Education

Anouschka VanLeeuwen – University of Utrech

Miguel Nussbaum Voehl – Catholic University of Chile

Barbara Wasson – University of Bergen

Rupert Wegerif – University of Exeter

Alison Clark-Wilson – Maths teacher (UCL KL)

Nicola Yuill – University of Sussex

Endnotes

1. https://www.nesta.org.uk/sites/default/files/the_challenge-driven_university.pdf
2. The limitations of literature reviews: Meta-analyses and reviews are informative and they tell us a lot about the effectiveness of collaborative approaches over other approaches to teaching and learning. However, they involve the mixing and comparison of often markedly different types of studies, across varying dimensions such as, education phase, curriculum area, culture, and task demands. They may also involve rather different approaches to collaborative group work. Calculating effect sizes and comparing effect sizes across studies is not an exact science and these are factors that may possibly explain different levels of reported success. There are also limitations associated with the individual studies included in meta-analyses. Probably the most fundamental limitation relates to their authenticity. When it comes to studies included in reviews these have often focused on short-term pieces of work involving particular task types that are designed for the purpose, may be novel and appealing and less relevant to the requirements of the school curriculum. These studies are thus not entirely natural or authentic and do not address the full needs of learners.
3. A best evidence synthesis focuses on the 'best evidence' in an area, the studies with the highest internal and external validity, using clearly specified inclusion criteria, and use information on effect size as an addition to a discussion of the literature being reviewed. Please note our earlier comments in Section one about the use of the terms collaborative and cooperative learning.
4. http://www.curee.co.uk/files/publication/1301578655/Hatties%20concept%20of%20visible%20teaching%20and%20learning.pdf
5. Bakhshi, H., Frey, C., and, Osborne, M. (2015) 'Creativity vs. Robots: The creative economy and the future of employment.' London: Nesta.
6. The project was funded by the Economic and Social Research Council's Teaching and Learning Research Programme. The evaluation took the form of a quasi-experimental design involving comparisons of teachers and classes of pupils that undertook the SPRinG programme with a control group of teachers and pupils – over the course of one school year. In all, the study involved 162 classes in primary and secondary schools, and 4,259 pupils aged five to 14. Multiple methods were used including start and end of year attainment tests and more focused short-term assessments of learning, systematic naturalistic observations and video observations of pupils and groups working in everyday classroom settings, attitudinal questionnaires as well as semi-structured interviews and field notes.
7. Harriot, T. (2014) 'An exploration of self-regulated learing during collaborative discussion.' M.Ed thesis.
8. Out of this class of 27, 12 are female, 20 are EAL, nine are on the Special Educational Needs (SEN) register, seven have FSM eligibility and 15 different ethnic backgrounds are represented.

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